SOME FEATURES OF EROSION BY UNCONCENTRATED WASH

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Erosion without valleys appears frequently to be regarded as due to the absence of all initial inequalities which might tend toward concentration of the run-off. It should follow as a corollary (and this too seems quite as often to be tacitly accepted), that such erosion cannot of itself perform a great geologic task, for, in nature, conditions of absolute equality are rare. If exemption from valley-cutting is due to such an exceptional condition, the wonder is that any broad slopes remain and that valleys do not branch indefinitely. Yet the observation is common that in loose and homogeneous material, the head of a gully is a perfectly definite thing, and that while some large gullies do arise from the union of smaller ones, this subdivision in a headward direction is not carried to microscopic dimensions.

If a broad slope without valleys is possible only with a nice equality of rills, its existence must be highly precarious, but it must be recognized that for every dissecting land-surface there is a degree of minuteness beyond which dissection will not go, and when this degree is reached the slopes are in no danger whatever of further dissection. The exact degree of minuteness of dissection (or what has sometimes been called the *texture* of the topography) depends on a number of factors not here discussed. The purpose of this paper is to point out and account for that limitation and to examine some of the topographic effects of erosion without valleys. It should be made clear that such erosion is not in the main dependent on equality of conditions, and that among rills or runnels on a broad hillside there is not always a tendency to grow larger, hence not always a contest for mastery or a struggle for existence.

Conditions assumed.—The simplest and typical case for the study of this principle is that of the plowed field or other surface of homogeneous material. A sod cover may temporarily hold its own against

channeling, even where steamlets are sufficiently concentrated to carry their loads and have some power to spare. Even here, however, the failure to cut channels may be due less to the actual withstanding of wear than to the retardation of currents and their continued subdivision, that is, the power which would result from concentration of the water is *prevented* rather than *withstood.* This case and all others which are complicated by the nature of the material or by special initial slopes are omitted from this discussion, which is concerned only with the simplest and most typical case of gradual concentration of run-off and its effects. If there is any categorical difference between the wash above the gully-head and that below, it must appear best where there is perfect freedom for either mode of activity to occur.

Loss of power due to subdivision of stream.—It is a well-recognized principle that the carrying power of a given flow of water is greater when concentrated into a single stream than when subdivided into several streams. Its application to deltas is familiar, in which case it might be shown that although the united stream were able to carry its entire load, a sufficient degree of subdivision into distributaries would bring about a condition in which no one of these could transport its sediment; in other words, while the volume of water and sediment are divided arithmetically, the power of the water decreases in a greater ratio.

The same principle applies equally well to the opposite case, that is, to the union of several streams into one. Applied to this case it may be stated thus: Given a stream whose power is more than necessary to carry its load; suppose this to be formed by the union of smaller streams, each of which in turn was similarly formed, and so on back to the origin of all in unconcentrated wash; previous to a certain degree of concentration, when all streams were below a certain size, all were overloaded and hence unable to cut definite channels. It is a commonplace observation that definite and continuous channels cannot be cut until a certain degree of concentration is reached; but the point here emphasized is that this condition may be and often is due to actual overloading of the primary streamlets with sediment.

Sudden change from overloaded to cutting condition.—There is

apparently a tacit assumption that the gully differs only in degree from the rill-mark, or what amounts to the same thing, that the behavior of the water in gully-making is the same in kind but differing in degree from the behavior of water in rills. The attendant assumption is that the change from the earlier condition to the later is gradual. A point to be emphasized is that the two conditions differ fundamentally, not in degree but in kind, and that the change from one to the other is sudden. It will be seen that this harmonizes with the common observation that heads of gullies in homogeneous unconsolidated material and having a simple history, are perfectly definite as to form and location.

All streamlets above the point where continuous valley-cutting begins, are here conceived of as overloaded, hence wandering, braiding, etc., according to well-known habits. Their union is, however, to some extent progressive, and when a certain stage is passed, the power is more than necessary for the load, and then definite, progressive down-cutting begins. It is unnecessary to show just how such down-cutting favors further concentration of rills at that point and therefore when once begun, goes on at an increasing rate. It may, however, be said that the progressive union of overloaded rills is to a large extent fortuitous.

Terms.—The characteristic suddenness of the change from the overloaded condition of the small streamlets to the cutting condition after a certain degree of concentration has been reached, makes it desirable that these conditions should be designated by distinctive names. No such distinctive names are in use, for the good reason that the distinctive character of the streamlets previous to this degree of concentration, seems not to be generally recognized. In the vast majority of cases the word "rill" seems to be applied to such cases, but no essential characteristic is implied by that term except smallness. In the absence of a more specific term, and for the purposes of this discussion, the word "rill" will be used to indicate such a streamlet in an overloaded condition, that is previous to the degree of concentration necessary to cut a gully. It is not necessary to specify the want of permanence since that is a necessary corollary. The condition succeeding that of the rill is equally without a distinctive term and there seems to be nothing to do but to use the word "gully stream'

for one in that condition, since the making of a gully is its characteristic function.

The whole area over which rills alone are formed may well be spoken of as subject to "unconcentrated wash." This term is necessarily relative, for even a drop of water represents a degree of concentration and there is no categorical distinction until the cutting stage is reached. The terms "sheet flood" and "sheet wash" are appropriate both in a descriptive and a technical sense for certain phenomena, generally in arid regions, where the run-off from torrential rains descends a slope in visible sheets. The same terms are misleading when applied to the ordinary phenomena of unconcentrated wash. The "sheet" in this latter case is rather a net work of constantly changing pattern.

Down-cutting by unconcentrated wash and "overloaded streams."—It will probably not be questioned that unconcentrated wash may and commonly (perhaps universally) does degrade that part of a slope which lies above gully-heads. If the assumption made above be correct, we then have the case of degradation being performed by currents which, according to our accepted terminology, are overloaded. It is difficult to deny that this is the case. If it seems to involve a contradiction of terms, it may be necessary to define an overloaded stream (if the term be retained) not as one which deposits at a certain place more than it removes but as one which behaves in a certain way with reference to its load. The main features of such behavior are the building of bars, the shifting of channels, subdivision and braiding, and above all, the inability of the streams to incise any one channel beneath the level upon which it wanders.

It would be a mistake to assume that all streams which build bars, anastomose, shift their channels and "braid" are of necessity aggrading their valleys or even that they are not degrading them. The relations between these phenomena of "overloaded streams" on the one hand and aggradation on the other is not so simple as that. It may safely be assumed however that some of the conditions which favor anastomosing, etc., are also favorable to aggradation. The classical example of an "overloaded stream" (the Platte) is quite probably aggrading its valley at the present time in that part where the phenomena listed above are most pronounced, and it has surely

aggraded it recently, but locally the same phenomena are well exemplified where the valley is distinctly terraced, the terraces and flood-plain all sloping toward the stream indicating progressive down-cutting.

If rills running over loose materials may be regarded as overloaded streamlets, and if it be assumed that the surface of a ridge is washed by such streamlets behaving as here described, and capable of carrying away from a given point more material than they bring, we have the conditions for the continued down-cutting of broad slopes without cutting valleys and for the lowering of a ridge without its subdivision into hills; it may be at a rate which is uniform throughout its length. Thus a broad area consisting of hills and ridges of uniform height may be cut down in such a manner as approximately to preserve their uniformity of height and the flatness of the sky line.

St. Louis peneplain.—Before going further it may be stated that this discussion was not begun with an academic interest, but in an attempt to explain what appears to be a case of just such uniform down-cutting as is here assumed. The area in question is the St. Louis quadrangle and adjacent territory. It is a low plateau with a mature drainage system. The ridges and very narrow remnants of upland rise to such a uniform height that no physiographer would hesitate to pronounce them the remnants of a former plain of very faint relief (in this case a peneplain as shown by abundant evidence). Furthermore the supposition would be that the horizon of the former plain was approximately that of the present hilltops.

Above the uniform level of the hilltops are a few exceptional elevations of fifty feet or more. Capping these are deposits of typical Lafayette gravels from ten to twenty feet thick. No theory of the origin of the Lafayette formation which receives any credence, admits the supposition that these gravels might have been deposited on exceptionally high points in preference to a lower surrounding plain. If the elevations on which they now rest existed as such when the gravels were deposited, it would seem necessary to assume that the entire surrounding plain was buried by gravel to a depth equal to the height of these hills plus the thickness of the deposit on the hills. It must then be assumed that subsequent erosion was guided in such a manner as to strip practically the whole of this thick bed of gravel from the surrounding plain while leaving the thin deposit on

the hilltops. To avoid this improbable supposition it might be assumed that the gravels were laid down on a plain whose elevation is represented by that of the present exceptional hills and that a post-Lafayette peneplain was developed 50 or more feet lower.

Hypothesis of rill-wash applied to the St. Louis region.—As a modification of, or substitute for this last hypothesis, the following is suggested: After the deposition of the Lafayette gravels on a nearly flat surface, uplift followed and the area was maturely dissected by a drainage system which was to some extent ready made, having held over from former conditions and which, therefore, to a certain degree, began its work simultaneously on the entire area. The gravel was in the main removed, except from a few patches between the head waters of streams flowing northwest to the Missouri and others flowing southeast to the Mississippi. It remained in these places partly because they were flatter and therefore less subject to erosion, and partly because, lying between headwaters, they were the last to be reached by erosion. With the exception of these spots the topography of the area was then one of comparatively even-topped ridges and valleys, but without flat uplands. Both while this dissection was in progress and subsequently, unconcentrated wash (as described above) lowered these ridges fifty or more feet. This was not effective on the gravel-covered hills, partly because of their relative flatness, but largely because percolation obviated wash.

The difficulty in such a conception lies in the uniformity of the down-cutting of all the ridges and the consequent preservation of the typical form of a dissected peneplain. This arises from our habit of thinking of rills as small rivers, each incising its own little valley and absorbing its neighbors as soon as a slight advantage has been gained. If the above theoretical reasoning pertaining to rill-wash be correct, this difficulty disappears. The struggle for existence (so characteristic of gullies) disappears from the community of rills as soon as each is seen to be overloaded. Stability then takes the place of instability and there is no longer any difficulty in maintaining an undissected slope while degradation proceeds. Under these conditions a large number of subequal ridges constituting a dissected plain will be degraded at a subequal rate.

It should be made clear that the correctness of the theoretical

reasoning above is not dependent on its application to the St. Louis region. This illustration is not brought forward to prove the argument but to show the nature of the problem in which the question occurs.

It should also be noted that the case of uniform down-cutting over a wide area implies a mature drainage system throughout. In the first dissection of a plateau this condition is reached first near the edge, hence the whole plateau cannot be simultaneously lowered. The erosion of an uplifted peneplain may, however, begin with a ready-made drainage system, the whole of which soon becomes incised. The whole area has, therefore, something of an even start in down-cutting.

Bearing of these principles on profile, and cross-section of valleys.— Returning to the principles, let us examine their bearing on the profile and cross-section of the young valley. Whether there is or is not any progressive union of overloaded rills, the power of such wash increases as the slope is descended, though it is not necessary to assume that the rills become less overloaded, for their load is likewise increasing. The reason for the increase of power lies in the increased amount of water. It is to be assumed that the fall of rain is equal throughout the slope, but since some of the descending water fails to percolate, the amount which joins the run-off is cumulative as the slope is descended. The effect of increasing power in this case is *increasing slope.*

Increase of slope as the result of increase of power is contrary to our customary conceptions gained from constant attention to rivers in which the reverse is usually true. A brief statement of the geometrical principle involved may therefore be necessary. Where a current is limited in its down-cutting by a certain level beneath which it cannot cut, additional power results in cutting nearer to that level and flattening the profile. Where the opportunity for down-cutting is not thus limited, the current is free to cut downward in proportion to its power and the effect of progressively increasing power is *a progressively steepening profile.* This is the case where a cutting stream encounters a fall. Both the principle and the form are illustrated in the rapids above all falls. However low the fall may be, it removes the upper stream entirely from the influence of the limiting level

below, and that level has no existence for the current above the fall. Nor is it necessary that the fall be vertical; the principle is the same in the approach to a cataract or cascade or other exceptionally steep slope, though its application is less simple.

Applying this principle to the case of rill-wash, we recall that the end of the overloaded condition and the beginning of gully-cutting is sudden. The effect of this is a steep offset which allows the rills to cut down without reference to any lower limit. The effect of this, in turn, is progressively increased slope as the fall at the gully-head is approached. This gives, above the gully-head, a profile which is convex upward, which gives way in the young valley itself to a profile of decreasing slope, that is, one which is concave upward. It will readily be seen that this description fits the case of the simple gully developed on a simple slope. Indeed the compound curve thus formed is very general despite all complexities due to sod covering and initially complex slopes.

A similar convexity of the upper slope is seen in the cross-section of a young valley. The existence of the valley removes from the wash on at least the upper part of the slope, the influence of the level which limits down-cutting. In all cases, therefore, except where peculiar conditions are assumed, the wash increases in power for a small distance at least, while the slope is concurrently steepened, producing a curve which is convex upward. If the valley be deepening, this convexity approaches more or less close to the axis, and, if the deepening be sufficiently rapid, the convexity reaches the channel making the entire slope from hilltop to stream convex upward. Where this is the case, the down-cutting of the valley axis is sufficient to leave the rill-wash on the entire slope free from the influence of a lower limiting level. Where down-cutting is less rapid, the wash near the stream comes within the influence of a lower limit and shapes its profile according to the laws of streams, that is, it becomes concave upward. The result is the U-shaped valley. The point to be emphasized here is that not only does this form *not* imply a cessation of down-cutting, but that it does not even imply lateral corrasion by the stream. The only requisite is that the stream shall cut down slowly enough so as *not* to remove from the wash on the side slopes the influence of a lower limit. In the area mentioned near St. Louis

it is quite the rule that the sides of the smaller valleys are upwardly convex from top to bottom.

In the course of its development the young valley whose cross-section shows simple curves increasing in steepness as the axis is approached, exchanges these for compound curves as described above. The stage of development at which this exchange is made depends partly on the absolute rate of down-cutting of the axis and partly on the behavior of the wash. A full explanation of the latter would involve discussion of materials composing the surface. Observation indicates that with a given rate of down-cutting a loess cover is specially favorable to valleys, whose sides increase in steepness down to the axis, that is, are simple curves and upwardly convex.